TENSILE TESTS ON OPTICAL FIBRE CABLES USING DISTRIBUTED BRILLOUIN ANALYSIS

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Abstract: *On-site distributed strain measurements using an original Brillouin analyser were performed on cables using standard tensile test bench and on critical installations in the Swiss telecom network.*

1. Introduction

The present paper describes on-site strain tests performed using a novel instrument developed by our group, based on the local analysis of stimulated Brillouin interaction along optical fibres[1][2]. Brillouin gain spectrum analysis has been pointed out several times in the past for its potentiality for strain monitoring in installed telecommunication cables[3]. Such tests are of prime importance since strain is expected to drastically reduce the fibre lifetime, even if the stress is considerably lower than that which causes immediate break. Hereby local strain measurements on tensile bench tests and on installed operating cables are presented to validate the Local Analysis of Stimulated Brillouin Interaction (LASBI) as a powerful method for the characterisation and monitoring of optical links.

2. Description of the instrument

Stimulated Brillouin Scattering (SBS) is strongly dependent on local physical parameters of the optical fibre, since the scattered light experiences a frequency downshift ν_B with respect to the incident light proportional to the acoustic velocity within the fibre, this latter being function of strain and to a much lesser extent of temperature. SBS is therefore naturally used to achieve distributed sensors measuring these quantities, and numerous contributions in this field have been presented in the past few years[4][5].

The basic configuration of a distributed Brillouin sensor is simple: a strong light pulse (pump) is launched into the fibre. It crosses a weak CW lightwave (probe), that

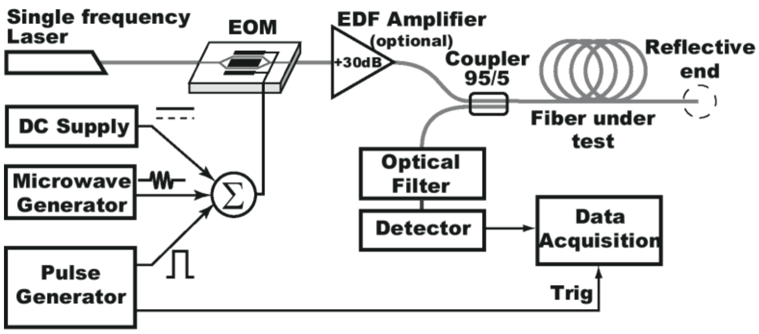

Fig. 1: *Experimental set-up for distributed Brillouin gain spectrum measurements.*

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propagates in the opposite direction. SBS occurs when pump and probe overlap, resulting in an amplification of the probe wave provided that the frequency difference between the two waves lies within the Brillouin gain spectrum of the fibre at that position. The frequency shift ν_B has to be measured to obtain the essential information on strain and temperature distribution. The experimental set-up of our configuration is schematically shown in *Fig. 1*. This set-up has the key advantage to require only one laser source, the CW probe and the pump pulse being generated at their proper frequency by the electro-optic guided-wave modulator[1][5]. This configuration allows to obtain meter spatial resolution for a 10 km range. A 1 MHz accuracy on the determination of the Brillouin shift ν_B is observed, corresponding to a 2×10^{-5} ε strain resolution and to a 1 K temperature resolution[4].

3. Local Strain Measurements

Some measurements on bare fibres and on fibre cables during tensile strain tests and after installation are presented in this section. In sub-section 3.1 and 3.2 the temperature was checked to be uniform all along the fibre, so that Brillouin frequency shift is to be attributed only to local strain.

3.1. Calibrated measurements on bare fibres

Along a 12 meter U-shaped aluminium beam (*Fig. 2*), three segments of a fibre have been tightly attached with different kind of glues. A fourth segment of loose fibre has also been placed on the same structure for control and reference. The beam experienced an elastic bending under its own weight using either a cantilever asymmetric configuration (fixed at one end) or a symmetric configuration (central support). In both cases the attached fibres were subject to a particular type of elongation. The relative strain has been locally measured using the LASBI system and compared with the calculated theoretical strain distribution. The measured and the theoretical strain distributions are shown in *Fig. 3.a* and *Fig. 3.b*, clearly demonstrating the very good agreement between predictions and measurements.

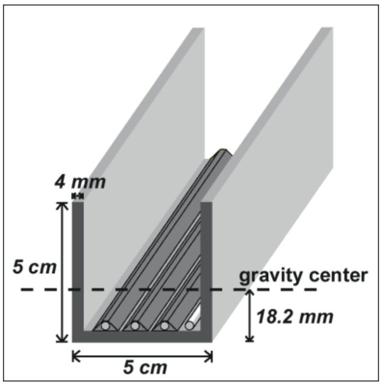

Fig. 2: *Aluminium structure incorporating three tightly attached fibres and a loose fibre.*

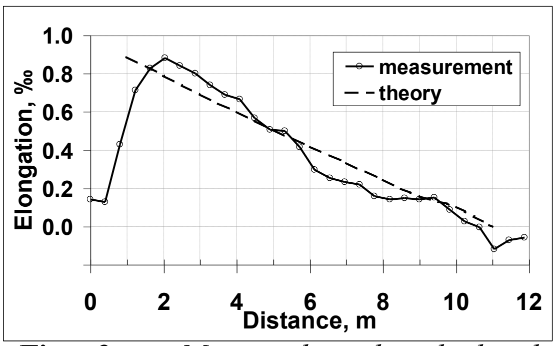

Fig. 3.a : *Measured and calculated strain distribution in the asymmetric bending configuration*

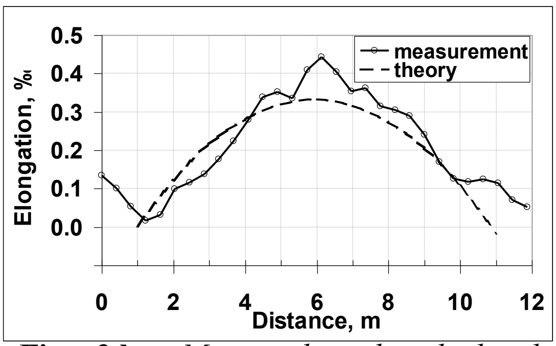

Fig. 3.b : *Measured and calculated strain distribution in the symmetric bending configuration*

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3.2. Local strain measurements on optical cables subjected to tensile tests

Another test was performed to check the resistance of a telecommunication cable when a strong tensile load is applied. This classical test is achieved using a pulley system, as shown in *Fig. 4*, and provides significant information about the cable buffering capability for fibres bundled in the cable. In particular this test is decisive to determine the critical pulling force at which the fibres start to be strained.

In *Fig. 5* the Brillouin distributed measurement using this pulley system shows a non-uniform fibre elongation over the cable length for different loads. The fibre is clearly less strained at the pulleys position. The total fibre elongation can be easily determined by integrating the local elongation over the entire cable length, as shown in *Fig. 6* for different tensile forces. The critical pulling force is clearly observed and the fibres start to elongate linearly for a larger applied force. This is in perfect agreement with other measurement of the total elongation, performed using a classical technique based on phase delay measurements. The Brillouin local analysis has the further advantage to measure the peak elongation, that is the relevant parameter for fibre lifetime expectation and that may be significantly larger than the average elongation, as shown in *Fig.5-6*.

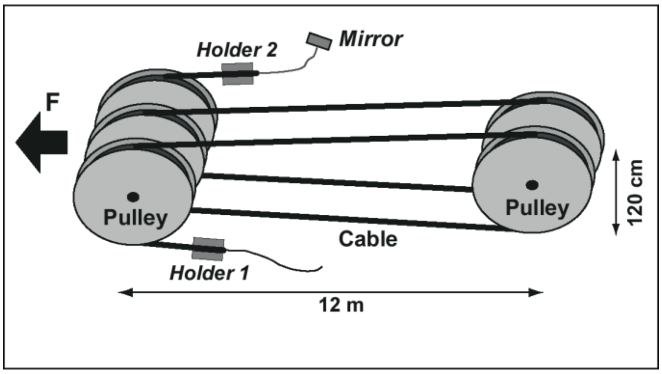

Fig. 4 : *Traction bench for testing cable resistance to tensile force. Longer cable segment can be checked thanks to the pulley system*

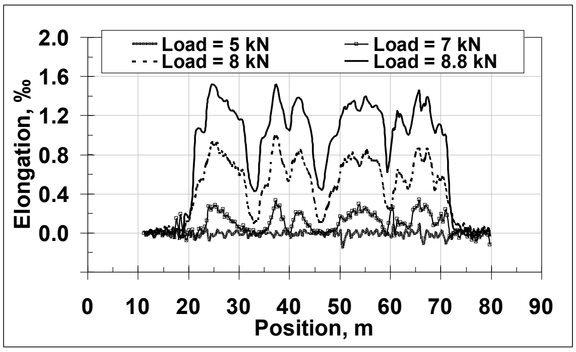

Fig. 5: *Distributed measurement of the elongation of a fiber in a cable stressed by the system shown in Fig. 4*

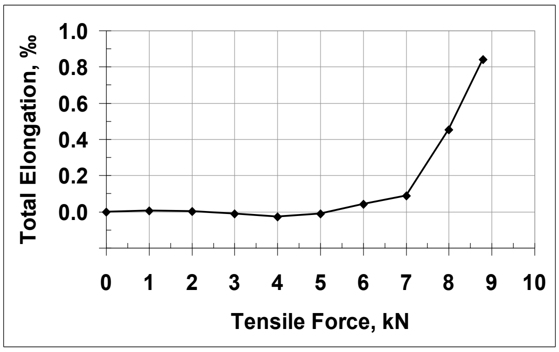

Fig. 6*: Total fiber elongation over the full cable length for different tensile force.*

3.3. Strain measurements on installed aerial optical links

Fibre cables are built such that their tensile resistance can be attributed mostly to the use of aramid yarns, that bear almost all the tensile load placed on the cable with little to no load transmitted to the optical fibres. In critical installations operators may be concerned about the presence of excess strain in optical fibres, especially in the case of aerial cables. A local strain measurement has been performed on an aerial optical link of the Swisscom network in the Swiss Alps (*Fig. 7*). This installation was particularly critical regarding the 600 m elevation difference and the long 300 m free range experienced by the cable. Fig. 7 shows that along the aerial section of the cable

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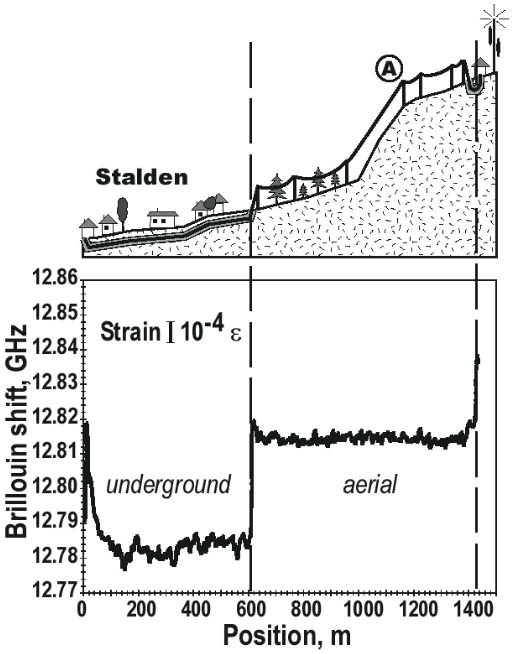
a flat response is observed for strain, so that strain is confirmed to remain within the very low level of 10^{-4} ε over the entire aerial range.



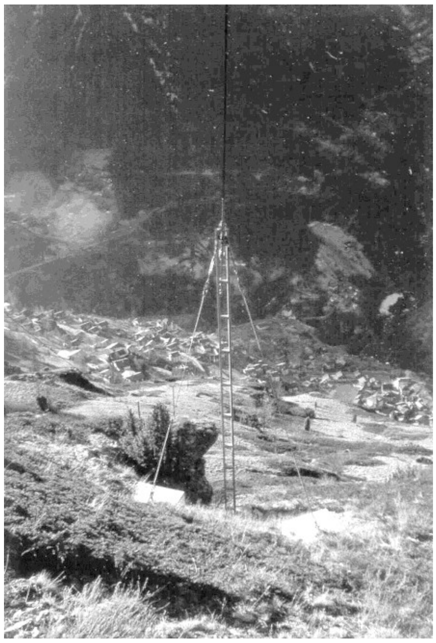


Fig. 7 : *Strain measurement on an aerial optical link in the Swiss Alps. In the picture the post at position A is shown.*

Conclusions

The local analysis of stimulated Brillouin interaction has clearly demonstrated its capability to measure local strain along optical fibres. Many on-site measurements were performed on critical installations of the Swisscom network, showing so far no occurrence of strain in excess of 10^{-4} ε for cable-bundled fibres. Our intrinsically stable instrumental configuration demonstrated its ability to measure real installations, even in an adverse environment.

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